ENERGY TECHNOLOGY AND GOVERNANCE PROGRAM

Assessment of the Impact of High Levels of Decarbonization and Clean Energy on the Electricity Market and Network Operation in Southeast Europe

– Executive Summary of Final Report –

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1. EXECUTIVE SUMMARY

The US Energy Association (USEA), in partnership with the US Agency for International Development (USAID), and working with its consultants, has completed this study for the 15 members of the Electricity Market Initiative (EMI), designed to evaluate the impacts and implications of deep decarbonization and clean energy integration on the markets and the grid of Southeast Europe (SEE).

Rationale and Background. As we enter 2022, we are at an inflection point with regard to electricity and natural gas issues in SEE, and there are a number of critical, multi-faceted issues facing EMI members, regulators, policy makers, and other stakeholders in the region. These include:

- Changing Generation Mix.
  - Can the tripling or quadrupling of renewable energy sources (RES) replace most if not all of the existing lignite and coal generation capacity? What other types of new capacity – particularly natural gas generation - may be required to meet customers' needs?
  - Do the EMI countries have the market, interconnection and permitting frameworks in place needed to attract, build and finance all the new RES projected by 2030?
- Impacts on Wholesale Power Prices.
  - To what extent will wholesale power prices change (rise), in conjunction with a tax on CO2, as a result of this myriad of transitions?
  - How much of a price increase is acceptable to achieve other objectives?
- Reducing CO2 Emissions.
  - What are the impacts of substantially changing the generation mix in SEE on reducing CO2 emissions to mitigate climate change?
  - Is the resulting level of emissions reduction acceptable? If we add substantial natural gas generation, what is the right level of fuel supply diversity?
- Satisfying Reliability Needs and Network Stability.
  - Can the existing grid and planned additions absorb all the projected RES and other generation capacity without overloads or reliability concerns?
  - Can we accept anything less than the current level of power system reliability?
- Relying on Others for Power Supplies.
  - What level of net electricity imports from other countries or regions will be required with this new generation mix?
  - What level of import dependence is appropriate or acceptable?

By evaluating the impacts of high levels of retirement and decommissioning of lignite and coal generation in SEE by 2030, this study answers the first questions in each issue above – the quantitative ones - but not the second question – the policy ones. However, the results of this analysis are intended to inform both the EMI members, and those who must answer the second set of questions.

Much has changed in the past year, as policy makers in several EMI countries have initiated or adopted National Energy Climate Plans (NECPs), passed climate-related legislation, and adopted green scenarios as their standard for planning. Ten-Year Network Development plans now anticipate retiring or decommissioning large shares of existing lignite and coal generation, and the EMI members need to understand the impacts of doing so, so in late 2020, USEA agreed – with support from its consultants EIHP and EKC - to study the impacts of strong actions to mitigate CO2 emissions.

In addition to helping the EMI members better plan their systems about a decade in advance to ensure longer-term stability, this study also reveals the major challenges of making that transition. The questions above show that this transition will require highly proactive involvement by the TSOs, generation companies (both public and private), NRAs, policy makers, and the private sector.

Approach. To develop this study, we started with the EMI members' current plans for their resource mix in 2030, and decreased the level of lignite and coal capacity in SEE well beyond those levels. In addition, this study includes high levels of RES (wind and solar) adoption, and a strong CO2 tax by 2030. The key factors we decided to measure included the impacts of such changes on wholesale power prices, CO2 emissions, the change in the generation mix, net electricity exchange, and the reliability of the grid.

As inputs and scenarios, this analysis projected the following:

- We more than tripled wind generation in SEE, and quadrupled solar capacity, from about 12 GW today to 42 GW in 2030. This was several GW higher than the reference case in EMI's 2020 RES study, reflecting how RES applications, projections, and targets continue to rise.

- We retired vast amounts of lignite and coal capacity, under three scenarios: a) reference (about a 50% reduction); b) moderate (about a 67% reduction); and c) aggressive (close to an 80% reduction), as shown in Figure 1 below. The reference case represents what is already in each country's resource plans, showing their existing high level of commitment to decarbonization.

							In comparison to 2030		In comparison to today (2018)		
Lignite + Coal	Total installed capacity in 2018	Total Decomissioned capacity till 2030	Total NEW capacity till 2030	Total capacity in operation in 2030 in Referent scenario	Total capacity in operation in 2030 in Moderate scenario	Total capacity in operation in 2030 in Extreme scenario	Rate of capacity change - Moderate scenario	Rate of capacity change - Extreme scenario	Rate of capacity change - Referent scenario	Rate of capacity change - Moderate scenario	Rate of capacity change - Extreme scenario
OST	0	0	0	0	0	0					
NOSBiH	1,850	628	410	1,632	1,442	1,166	-11.6%	-28.6%	-11.8%	-22.1%	-37.0%
ESO EAD	3,920	3,920	0	0	0	0			-100.0%	-100.0%	-100.0%
IPTO/ADMIE	3,870	3,870	0	0	0	0			-100.0%	-100.0%	-100.0%
HOPS	297	0	0	297	192	0	-35.4%	-100.0%	0.0%	-35.4%	-100.0%
KOSTT	960	432	450	978	528	264	-46.0%	-73.0%	1.9%	-45.0%	-72.5%
CGES	225	0	0	225	225	0	0.0%	-100.0%	0.0%	0.0%	-100.0%
MEPSO	759	759	0	0	0	0			-100.0%	-100.0%	-100.0%
Transelectrica	4,105	1,870	0	2,264	771	428	-65.9%	-81.1%	-44.8%	-81.2%	-89.6%
EMS	4,034	263	656	4,428	3,632	2,508	-18.0%	-43.4%	9.8%	-10.0%	-37.8%
ELES	844	305	0	539	0	0	-100.0%	-100.0%	-36.1%	-100.0%	-100.0%
TOTAL	**20,864**	**12,047**	**1,516**	**10,363**	**6,790**	**4,366**	**-34.5%**	**-57.9%**	**-50.3%**	**-67.5%**	**-79.1%**

Figure 1 - Changes in Lignite and Coal Generation by EMI Member from Today to 2030 – EMI Scenarios

- To replace these retiring units, we also assessed the EMI countries' current plans to add 9 GW of natural gas generation (most of which is in Romania, Bulgaria and Greece); add 5 GW of hydro plants; and add one new nuclear plant, in addition to the large amount of RES additions mentioned above. Figure 2 below shows our final resource mix for 2030, for each scenario.

EMI Member	WPP installed capacity (MW)	SPP installed capacity (MW)	HPP installed capacity (MW)	TPP Capacity (MW)			TOTAL CAPACITY (MW)		
				Referent	Moderate	Extreme	Referent	Moderate	Extreme
AL	384	445	2949	300	200	100	4078	3978	3878
BA	580	100	2493	1632	1442	1166	4805	4615	4339
BG	948	3216	3207	4728	4070	3470	12099	11441	10841
HR	1300	600	3117	981	876	684	5998	5893	5701
GR	7000	7700	4545	7768	7167	6493	27013	26412	25738
XK	336	150	434	978	528	264	1898	1448	1184
MK	443	563	1086	586	586	586	2678	2678	2678
ME	243	250	1117	225	225	0	1835	1835	1610
RO	5255	5054	6784	10055	8562	6889	27148	25655	23982
RS	4553	508	3035	4829	4033	2909	12925	12129	11005
SI	150	1866	1295	1757	990	937	5068	4301	4248
TOTAL	**21192**	**20452**	**30062**	**33837**	**28678**	**23498**	**105545**	**100385**	**95204**

Figure 2 – Generation Resource Mix in Southeast Europe in 2030, by Scenario

- We employed a carbon tax of 67 Euros per ton in 2030, which significantly lowers the dispatch of lignite and coal. When the study began, this assumed price was higher than the current ETS level, but as the study progressed, carbon prices rose sharply, and exceeded this input in 2021.

- We upgraded and reinforced the regional network based upon the EMI members plans for such additions by 2030, and conducted our grid reliability analysis down to the 110 kV level.

- We evaluated conditions that included average and dry hydro, recognizing that the latter condition – not an uncommon one - would require much greater use of thermal resources and imports, and stress the markets and the grid to a greater extent.

- We surmised that all markets in SEE will be coupled by 2030 (one robust short-term market for power region-wide)

This work, using the Antares model for the market analysis, and PSS/E for the network work, created a robust and verified regional power system model consisting of:

- 8,578 buses
- 10,050 branches
- 3,360 loads
- 1,521 power plants
- 3,745 transformers

- 149 switched shunts
- 4 DC lines

USEA believes that this framework – developed in close collaboration with the EMI members - is the most comprehensive and reliable in the region. We intend to keep it up to date, while also training all EMI members to ensure that they have the ability to conduct their own studies using these tools.

Key Findings. From a broad perspective, here are the major conclusions of the analysis described above.

1. **The region cannot remove a huge percentage of the coal and lignite generation in SEE by 2030 without large increases in gas generation** (other technologies are not yet ready to fill the gap). In many ways, gas needs to be the bridge fuel to a decarbonized future. This also emphasizes the importance of a diversity of gas supply to meet the need for new gas generation, and the need for pipeline infrastructure and finances to realize those additions.

2. **Major increases in wind and solar renewables by 2030, while highly desirable, will not fill the gap from coal retirements**, due to their intermittency and low capacity factors (average of 20%).

3. **We need a competitive, geographically broad market and appropriate policies to mobilize the capital from the private sector required to finance this massive change in the generation mix.**

   A large market in SEE, where the borders are coupled and competitive, will attract the private sector, and support the EMI countries – especially the WB6 – to mobilize the capital and adopt the policies required for this transition. Separated markets will have the opposite effect.

   We estimate that to increase RES capacity (wind and solar) from about 12 GW today to 42 GW in 2030 – the EMI members' base case – will require $34 billion in new capital across the region, including $10 billion in the WB6 countries. Apart from the cost, it is not clear whether the investment climate, interconnection procedures, and permitting requirements are in place or sufficiently clear in a number of countries to enable these RES additions to come to fruition.

   The addition of 9 GW of natural gas generation could require another $9 billion, and the addition of 5 GW of hydro billions more, for a total of close to $50 billion required for regional changes in the generation mix alone.

4. **The lignite and coal units that remain will be competitive in the market, and will need to operate at high capacity factors to maintain system reliability for the time being**.

5. **With all these changes, wholesale power prices could rise 15% or more by 2030, particularly if carbon fees in Europe remains high (see Figure 3)**. The

transition is not free. This raises the question of whether regulators will agree to pass on these added costs to customers.

6. **Electricity imports to SEE could rise considerably as we decarbonize the region.** This leads to the question of where those imports will come from, and whether the neighboring countries will have enough power to export if they are going through the same transition.

   In the case of a "zero balance", where imports to SEE are not readily available, there would be some electric energy not served (EENS), plus much higher wholesale power prices. Increasing EENS could also lead to social unrest and turmoil, and is thus highly undesirable.

7. **Given the strong existing network and plans for new lines and substation additions, the wholesale grid remains reliable throughout this transition**, with only a few elements that appear overloaded, which TSOs and grid owners can readily address between now and 2030.

We now show through charts the figures that support these key findings.

Market Analysis. Figure 3 below summarizes many of the key results of our market analysis for Southeast Europe, across the full range of scenarios, followed by our summary of the future impacts.

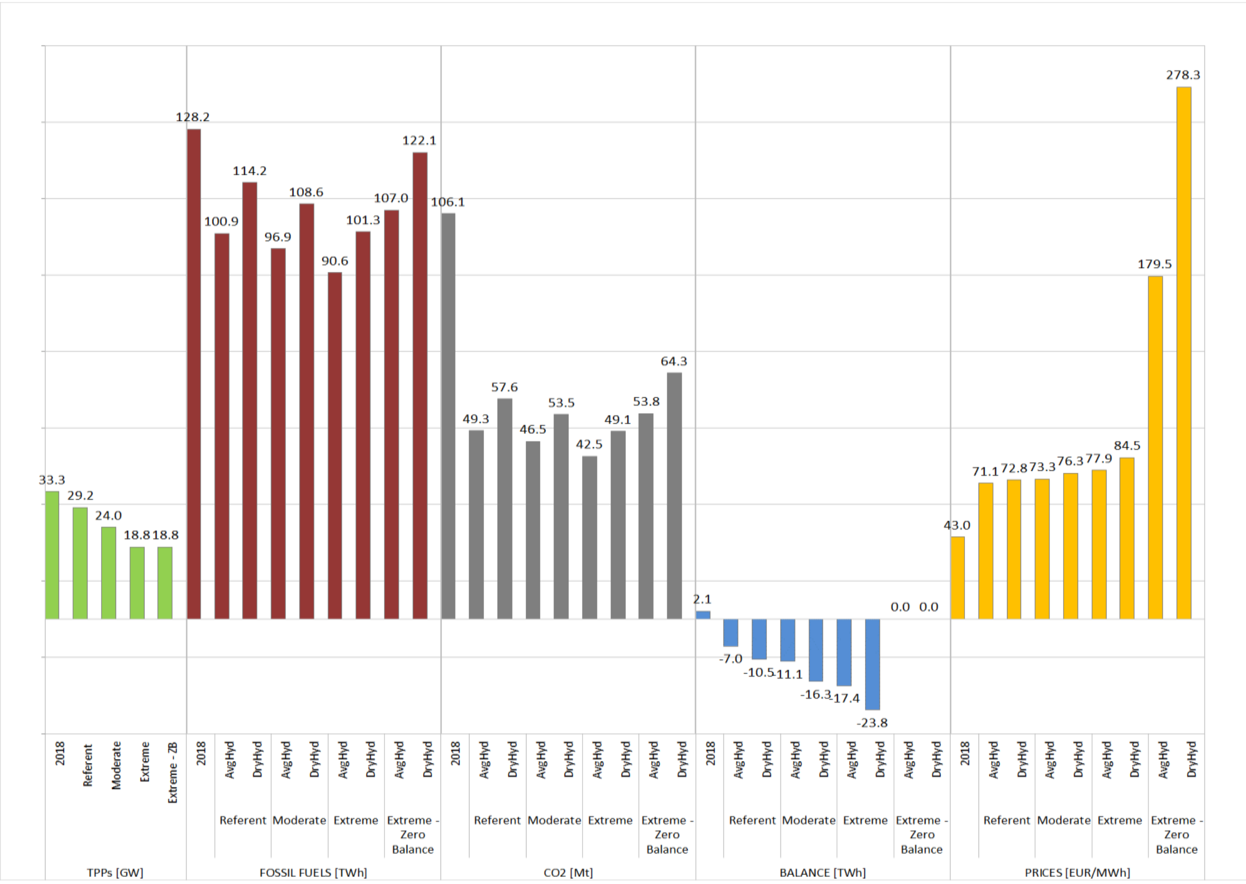


Figure 3 – Projected Market Changes in SEE by 2030

Thermal Generation. As shown in the first (green) columns on this chart, the total amount of thermal power plants (TPPs) does not fall nearly as much as the retirements of lignite and coal would suggest, because the EMI countries plan to add large amounts of natural gas generation. From 2018 to 2030, the installed capacity of TPPs would fall from 33 GW in 2018 to about 19 GW in 2030 (about 45%), even when we remove four-fifths of the lignite and coal capacity.

Fossil Generation. As shown in the second (brown) columns, total generation from fossil plants decreases with greater decarbonization, and it is always higher in dry hydrology conditions. It is noteworthy that when we assume limited ability for imports from outside SEE (the last two brown bars), the need for TPPs (even the most expensive ones) must rise to satisfy demand for power.

As a result of these changes, plus CO_2 price impacts, the share of lignite and coal generation in 2030 falls sharply, and ranges from 6% to 10% of regional needs compared to about 40% in 2018, as shown in Figure 4 below.

CO_2 Emissions. As shown in the grey columns, lower fossil generation leads to a substantial reduction in CO_2 emissions, by about half. This is a much lower share than the reduction in lignite and coal capacity, due to gas additions and strong utilization of the remaining lignite units, which are in a better market position than the retired units.

Imports and Exports. The blue bars demonstrate that regional imports will increase substantially, going from a net export position to one in which the region imports up to 10% of its needs. Specific countries change from being importers to exporters, and vice versa, depending on the level of natural gas and renewable additions, lignite retirements and hydrology (assuming all renewable targets are met).

Wholesale Power Prices. The yellow bars show that wholesale power prices need to rise considerably to meet this future state (by 65% to 95% from 2018 to 2030, depending on the scenario). The greater the level of decarbonization, and the drier the hydrology, the higher the prices. By 2030, the prices in each EMI country are virtually identical, given our assumption that the markets between all 11 countries are coupled by then, plus the high level of interconnectivity.

The largest element of this price increase is the carbon tax. In 2018, there was no carbon tax in WB6 countries, and much lower CO_2 prices in the EU countries. Renewables actually lower the wholesale price). This study used a projection of about 66 Euros per ton in 2030, and it could have been even higher, since current ETS prices have already exceeded that level.

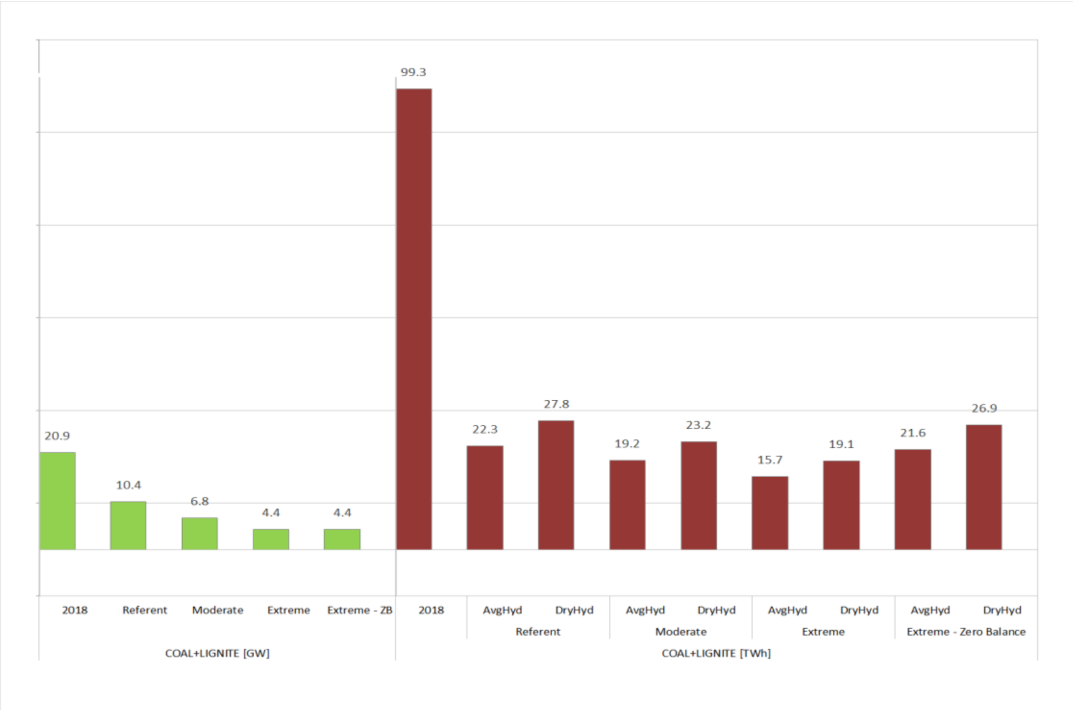


Figure 4 - Projected 2030 Changes in Coal and Lignite Capacity (GW) and Generation (GWh) Versus Today

As mentioned, natural gas becomes the bridge fuel, with substantial increases in capacity (GW) and output (TWh) required to meet customer demands, as shown in Figure 5 below. Output from gas-fired plants needs to triple, and comes close to quadrupling in some scenarios.

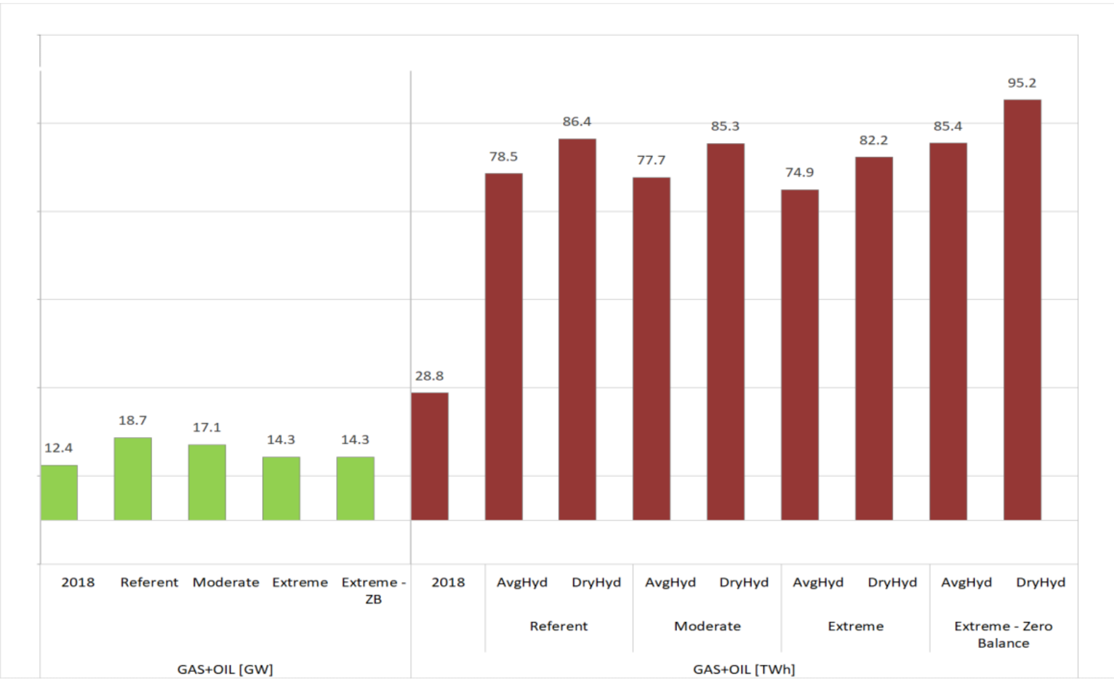
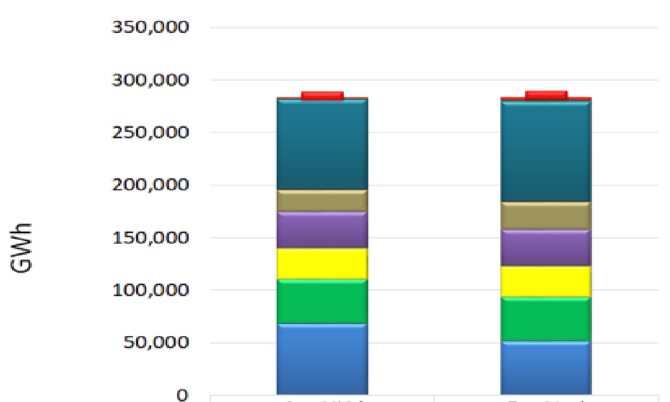


Figure 5 – Projected 2030 Changes in Natural Gas Capacity (GW) and Generation (GWh) Versus Today

As mentioned above, in the most extreme (but not implausible) case, in which other European countries do not have the option to export power needed for their citizens, SEE could experience a shortfall in the ability to satisfy customer demands. This is true even with all the additions of natural gas, renewables and hydro capacity planned by 2030 (see the level of Energy Not Served (ENS) in Figure 6 below).

While a small share of total consumption, this would have a major impact on power prices. Depending on how one values the load not served, or the level of emergency imports, annual wholesale prices could double or triple. This could further lead to social unrest and disruptions, and is clearly an undesirable outcome.

Some countries are much better positioned than others in this possible future condition. The EMI will be working with its members in the coming months and years on "resource adequacy and flexibility" studies to help ensure that they avoid such a situation.



	AvgHYd	DryHyd
	Extreme-zero Balance	
ENS	1,052	2,928
Other	1,022	1,027
Gas	85,285	94,938
Coal	640	935
Lignite	20,923	25,951
Nuclear	34,458	34,458
Solar	30,214	30,214
Wind	41,414	41,414
Hydro	68,492	51,676
Consumption	284,937	285,787

Figure 6 – Energy Not Served in Zero Balance and Hydro Scenarios

Finally, we conducted a highly detailed analysis of the impacts of lignite retirements, gas additions, renewable and hydro additions on the grid, across the thousands of network elements mentioned above. As in prior EMI studies, we found that the grid in SEE is extremely robust (much more so than other parts of Europe). Even in the most stressful scenarios, we found a maximum of 28 elements that would be stressed above their operating capacities in 2030, as shown in Figure 7 below. Of those, only 10 were overloaded beyond the standard of 130% of their limits.

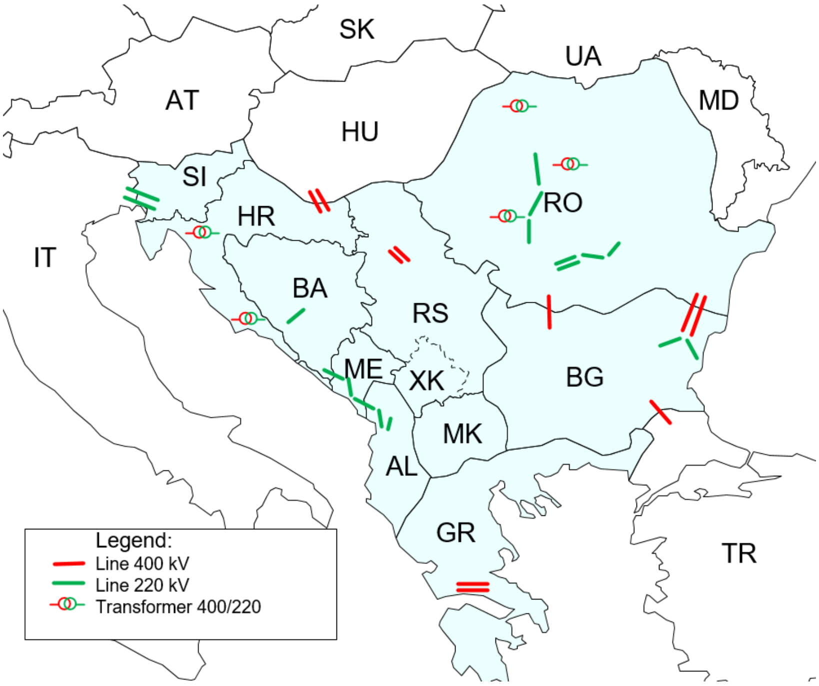


Figure 7 – Network Constraints in Southeast Europe in 2030 with Major Generation Changes

A number of these situations are within countries, while others cross borders. In many if not all cases, the EMI members were already aware of these potential bottlenecks. By highlighting these stresses, this study helps the EMI members ensure that these network elements do not limit the system's reliability, or its ability to support electricity markets, imports or exports in the future.

In sum, under the conditions we evaluated, we see no major new investments in the network in SEE required to accommodate all the changes that will take place through 2030.